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3 What is claimed is:

1. A phase shift mask for use with light at a wavelength comprising:

a first phase shift section, a half tone section, and a second phase shift section;

said first phase shift section adjacent to said half tone section;

said half tone section adjacent to said second phase shift section;

said first phase shift section and half tone section changing the phase of incident light by about 180 degrees with respect to said second phase shift section.

2. The phase shift mask of claim 1 which further includes

said first phase shift section comprised of a first phase shift region of a mask substrate;

a trench in said first phase shift region; and

said half tone section comprised of (i) a half tone region of said mask substrate and (ii) a half tone layer over said half tone region;

said second phase shift section has about a 0 degree phase shift.

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3. The phase shift mask of claim 1 which further includes:

said first phase shift section comprised of (i) a first phase shift region of a mask substrate and (ii) a first trench in said first phase shift region;

said half tone section comprised of a half tone region of said mask substrate and a half tone layer over said half tone region; said half tone layer has a transmittance between about 3 and 30%; and

said second phase shift section has about a 0 degree phase shift.

- 1     4. The phase shift mask of claim 1 which further includes :  
2                     said first phase shift section comprised of (i) a first phase shift region of  
3     a mask substrate and (ii) a first trench in said first phase shift region; and  
4                     said half tone section comprised of a half tone region of said mask  
5     substrate and a half tone layer over said half tone region;  
6                     said half tone layer has a transmittance between about 3 and 30%;  
7                     said second phase shift section comprised of (a) a second phase shift  
8     region of said mask substrate and (b) a second trench in said second phase shift region;  
9                     said second phase shift section has about a 90 degree phase shift.  
10
- 11    5. The phase shift mask of claim 1 wherein said second phase shift region has about a 100  
12    % transmittance.
- 13    6. The phase shift mask of claim 1 wherein said half tone section has a transmittance that  
14    balances the light intensities transmitted through said first phase shift region and said  
15    second phase shift region so that the light intensities are about equal.
- 16    7. A semiconductor device formed by using the phase shift mask of claim 1.  
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- 19    8. A phase shift mask for use with light at a wavelength comprising:  
20                     a mask substrate having a first phase shift region, a half tone region,  
21     and a second phase shift region;  
22                     said first phase shift region adjacent to said half tone region;  
23                     said half tone region adjacent to said second phase shift region;  
24                     a half tone layer over said half tone region;  
25                     said first phase shift region and half tone layer changing the phase of  
26     incident light by about 180 degrees with respect to said second phase shift region.  
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- 3 9. The phase shift mask of claim 8 which further includes a trench in said mask substrate  
4 in said first phase shift region; and  
5 said second phase shift region has about a 0 degree phase shift; and  
6 said half tone region has a transmittance between about 0.1 and 98 %.
- 7 10. The phase shift mask of claim 8 which further includes a trench in said mask substrate  
8 in said second phase shift region; and  
9 said first phase shift region has about a 0 degree phase shift;  
10 said half tone layer has a transmittance between about 3 and 30%.
- 11 11. The phase shift mask of claim 8 which further includes:  
12 a first trench in said first phase shift region; and  
13 a second trench in said second phase shift region; and  
14 said half tone layer has a transmittance between about 3 and 30%.
- 15 12. The phase shift mask of claim 8 wherein said half tone layer has a transmittance  
16 between about 3 and 30% .
- 17 13. The phase shift mask of claim 8 wherein said second phase shift region has about a  
18 100 % transmittance.
- 19 14. The phase shift mask of claim 8 wherein said half tone layer has a transmittance that  
20 balances the light intensities transmitted through said first phase shift region and said  
21 second phase shift region so that the light intensities are about equal.
- 22 15. A semiconductor device formed by using the phase shift mask of claim 8.
- 23
- 24 16. A phase shift mask for use with light at a wavelength comprising:  
25 a mask substrate having a phase shift region, a half tone region and an unshifted  
26 phase region;

- 1 a half tone layer over said half tone region;  
2 said phase shift region adjacent to said half tone region;  
3 said half tone region adjacent to said unshifted phase region;  
4 said phase shift region has about a 180 degree phase shift with respect to said  
5 unshifted phase region,  
6 said half tone layer has a phase shift of about a 180 degrees with respect to said  
7 unshifted phase region, said half tone layer has a transmittance between about 3  
8 and 30%; and  
9 said unshifted phase region has a shift of about 0 degrees.
- 10 17. The phase shift mask of claim 16 which further includes a trench in said phase shift  
11 region.
- 12 18. The phase shift mask of claim 16 wherein said unshifted phase region has about a 100  
13 % transmittance and about a 0 degree phase shift with the incoming light.  
14
- 15 19. The phase shift mask of claim 16 wherein said phase shift region has a phase shift  
16 such that light that at said wavelength transmitted through said phase shift region is  
17 shifted in phase by about 180 degrees relative to said light at said wavelength  
18 transmitted through said unshifted phase region.  
19
- 20 20. The phase shift mask of claim 16 wherein said half tone region has a transmittance that  
21 balances the light intensities transmitted through said phase shift region and said  
22 unshifted region so that the light intensities are about equal.
- 23 21. A semiconductor device formed by using the phase shift mask of claim 16.  
24
- 25 22. A phase shift mask for use with light at a wavelength comprising:  
26 a) a mask substrate has a first phase shift region, a half tone region and an  
27 second phase shift region;

- 1                   b) a half tone layer over said half tone region; said half tone layer has a  
2                   transmittance between about 0.1 and 98 %;
- 3                   c) said first phase shift region and half tone layer have an about 180 degree  
4                   phase shift with respect to said second phase shift region;
- 5                   d) said first phase shift region adjacent to said half tone region;
- 6                   e) said half tone region adjacent to said second phase shift region.
- 7    23. The phase shift mask of claim 22 wherein a first trench in said first phase shift region;  
8       said first phase shift region has about a 100 % transmittance.
- 9    24. The phase shift mask of claim 22 wherein said half tone layer has a transmittance  
10       between about 3 and 30% .
- 11   25. The phase shift mask of claim 22 wherein said second phase shift region has about a  
12       100 % transmittance.
- 13   26. A semiconductor device formed by using the phase shift mask of claim 22.
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- 16
- 17   27. A method for forming a single trench half tone phase shift mask for use with light at a  
18       wavelength comprising:
- 19                   a) providing a substrate having a phase shift region, a half tone region and  
20                   an unshifted phase region; said phase shift region adjacent to said half  
21                   tone region; said half tone region adjacent to said unshifted phase  
22                   region;
- 23                   b) forming a half tone layer on said substrate in said half tone region; said  
24                   half tone layer has a phase shift of about 180 degrees with said  
25                   unshifted phase region, said half tone layer has a transmittance between  
26                   about 3 and 30%;

- 1                   c)   forming a trench in said substrate in said phase shift region; said phase  
2                            shift region has an about 180 degree phase shift with said unshifted  
3                            phase region.  
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5   28. The method of claim 27 wherein said trench formed to a first depth such that light that  
6       at said wavelength transmitted through said phase shift region is shifted in phase by 180  
7       degrees relative to said light at said wavelength transmitted through said unshifted  
8       phase region.

9   29. A method for forming a half tone single trench phase shift mask for use with light at a  
10       wavelength comprising:

- 11                   a)   providing a substrate having a phase shift region, a half tone region  
12                            and an unshifted phase region and an opaque region;  
13                            said phase shift region adjacent to half tone region;  
14                            said half tone region adjacent to an unshifted phase region;  
15                   b)   forming a half tone layer on said substrate;  
16                   c)   forming an opaque layer on said half tone layer;  
17                   d)   forming a first resist layer on said opaque layer;  
18                   e)   removing portions of said first resist layer to form a first resist pattern  
19                            over said half tone region and said opaque region;  
20                   f)   patterning said an opaque layer on said half tone layer using the first  
21                            resist pattern as a mask form a first opaque pattern and a half tone  
22                            layer pattern over said half tone region;  
23                   g)   removing said first resist layer;  
24                   h)   forming a second resist layer over said opaque layer on said half tone  
25                            layer and said substrate;  
26                   i)   removing portions of said second resist layer to form a second resist  
27                            pattern over said unshifted region and said opaque region and to form  
28                            second resist layer openings over said phase shift region;

- 1           j)   forming a trench in said phase shift region; said trench has a depth so
- 2               that said phase shift region has a phase shift of 180 degrees with said
- 3               unshifted phase region;
- 4           k)   removing said second resist pattern;
- 5           l)   forming a third resist layer over said substrate;
- 6           m)   removing portions of said third resist layer to form a third resist layer
- 7               pattern over the opaque region and to form a third resist layer openings
- 8               to expose said phase shift region, said half tone region and an unshifted
- 9               phase region;
- 10          n)   removing said opaque layer from over said half tone region layer in said
- 11             half tone regions;
- 12          o)   removing said third resist layer.
- 13
- 14   30. The method of claim 29 wherein half tone layer has a 180 degree phase shift with said
- 15       unshifted phase region.
- 16   31. The method of claim 29 which further includes etching said half tone pattern to
- 17       control the transmission of the said half tone pattern.
- 18   32. The method of claim 29 wherein said substrate is a mask blank comprised of quartz.
- 19   33. The method of claim 29 wherein said half tone layer is comprised of a material
- 20       selected from the group consisting of: molybdenum silicide, molybdenum silicon
- 21       oxide, silicon nitride, and silicon oxinitride.
- 22   34. The method of claim 29 wherein said opaque layer is comprised of chrome.
- 23   35. The method of claim 29 wherein the patterning said opaque layer on said half tone
- 24       layer is performed using a reactive ion etch.
- 25   36. The method of claim 29 wherein said first resist layer is negative or positive type
- 26       photoresist.

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3 37. A method for a phase shift mask for use with light at a wavelength comprising:

4 a) providing a mask substrate having a first phase shift region, a half tone  
5 region and an second phase shift region;

6 b) said first phase shift region adjacent to said half tone region; said half  
7 tone region adjacent to said second phase shift region;

8 c) forming a first trench in said substrate in said first phase shift region;  
9 said phase shift region has an about 180 degree phase shift with said  
10 unshifted phase region, said first phase shift region has about a 100 %  
11 transmittance;

12 d) forming a half tone layer on said mask substrate in said half tone  
13 region; said half tone layer has a phase shift of about 180 degrees with  
14 said first phase shift region; said half tone layer has a transmittance  
15 between about 0 and 100 % ;

16 e) forming a second trench in said substrate in said second phase shift  
17 region; said second phase shift region has an about 180 degree phase  
18 shift with said first phase shift region.

19 38. The method of claim 37 wherein said first phase shift region creates a phase shift of  
20 about 270 degrees on incident light;

21 said second phase shift region and said half tone layer creates a phase  
22 shift of about 90 degrees on incident light.

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24 39. The method of claim 37 wherein said half tone layer has a transmittance between  
25 about 3 and 30 % .



- 1 40. A method for forming a half tone dual trench phase shift mask for use with light at a  
2 wavelength comprising:
- 3 a) providing a substrate having a first phase shift region, a half tone  
4 region and an second phase shift region and an opaque region;  
5 said first phase shift region adjacent to said half tone region;  
6 said half tone region adjacent said second phase shift region;
  - 7 b) forming a half tone layer on said substrate;
  - 8 c) forming an opaque layer on said half tone layer;
  - 9 d) forming a first resist layer on said opaque layer;
  - 10 e) removing portions of said first resist layer to form a first resist pattern  
11 over said half tone region and said opaque region;
  - 12 f) patterning said an opaque layer on said half tone layer using the first  
13 resist pattern as a mask form a first opaque pattern and a half tone  
14 pattern over said half tone region;
  - 15 g) forming second trenches in the substrate in the second phase shift region  
16 and partial first trenches in the first phase shift regions;
  - 17 h) removing said first resist layer;
  - 18 i) forming a second resist layer over said opaque layer on said half tone  
19 layer and said substrate;
  - 20 j) removing portions of said second resist layer to form a second resist  
21 pattern over said second phase shift region and said opaque region and  
22 to form second resist layer openings over said first phase shift region;
  - 23 k) forming a first trench in said first phase shift region; said first trench  
24 has a depth so that said first phase shift region has a phase shift of  
25 about 180 degrees relative to said second phase shift region;
  - 26 l) removing said second resist pattern;
  - 27 m) forming a third resist layer over said substrate;

- 1                   n)    removing portions of said third resist layer to form a third resist pattern  
2                            over said opaque region and to form a third resist layer openings to  
3                            expose said half tone pattern in said first phase shift regions, and said  
4                            half tone region and an second phase shift region;  
5                   o)    removing said opaque patterns from over said half tone pattern in said  
6                            half tone regions;  
7                   p)    removing said third resist pattern.

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10   41. The method of claim 40 wherein said first phase shift region creates a phase shift of  
11       about 270 degrees on incident light;  
12                        said second phase shift region and said half tone layer creates a phase  
13   shift of about 90 degrees on incident light.  
14   42. The method of claim 40 which further includes etching said half tone pattern to control  
15       the transmission of the said half tone pattern.  
16   43. The method of claim 40 wherein said substrate is a mask blank comprised of quartz.  
17   44. The method of claim 40 wherein said half tone layer is comprised of a material  
18       selected from the group consisting of: molybdenum silicide, molybdenum silicon  
19       oxide, silicon nitride, and silicon oxynitride.  
20   45. The method of claim 40 wherein said opaque layer is comprised of chrome.  
21   46. The method of claim 40 wherein the patterning said opaque layer on said half tone  
22       layer is performed using a reactive ion etch.  
23   47. The method of claim 40 wherein said first resist layer is negative or positive type  
24       photoresist.  
25  
26   48. A method of fabricating a semiconductor device the method comprising:

- 1           a) providing a phase shift mask comprising:
- 2               (1) a mask substrate having a first phase shift section, a half tone section
- 3                     and a second phase section;
- 4                     said first phase shift section adjacent to said half tone section;
- 5                     said half tone section adjacent to said second phase section;
- 6                     said first phase shift section and said half tone section have about a
- 7                     180 degree phase shift with said second phase section;
- 8                     said half tone section has a transmittance between about 0.1 and 98
- 9                     %;
- 10           b) transmitting radiation through portions of the phase shift mask to expose
- 11               a pattern of photoresist overlying a semiconductor workpiece; and
- 12           c) utilizing the patterned photoresist to fabricate a semiconductor device.
- 13   49. The method of claim 48 wherein said half tone section comprises a half tone region of
- 14       a mask substrate and a half tone layer over said half tone region, said half tone layer
- 15       has a transmittance between about 3 and 30 %.
- 16   50. The method of claim 48 wherein said phase shift mask further includes;
- 17               said first phase shift section comprises a first phase shift region of a
- 18   mask substrate;
- 19               a first trench in said mask substrate in said first phase shift region; and
- 20               said second phase section has about a 0 degree phase shift.
- 21   51. The method of claim 48 wherein said phase shift mask includes:
- 22               a mask substrate having a first phase shift region, a half tone region and
- 23   a second phase shift region;
- 24               a first trench in said first phase shift region; and
- 25               said first phase shift region has about a 0 degree phase shift;
- 26               said half tone layer has a transmittance between about 3 and 30%; and
- 27               a second trench in said second phase shift region.

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2 52. The method of claim 48 wherein said phase shift mask includes:

3 a mask substrate having a first phase shift region, a half tone region and  
4 a second phase shift region;

5 a first trench in said mask substrate in said first phase shift region; and

6 a second trench in said mask substrate in said second phase shift region;

7 and

8 said half tone layer has a transmittance between about 3 and 30%.

9 53. The method of claim 48 wherein said half tone region has a transmittance that about

10 balances the light intensities transmitted through said first phase shift region and said

11 second phase shift region so that the light intensities are about equal.

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13 54. A method of fabricating a semiconductor device the method comprising:

14 a) providing a single trench half tone phase mask comprising:

15 (1) a phase shift section, a half tone section and an unshifted phase  
16 section;

17 (2) said phase shift section adjacent to said half tone section;

18 (3) said half tone section adjacent to said unshifted phase section;

19 (4) said phase shift section has an about 180 degree phase shift with said  
20 unshifted phase section;21 (5) said half tone section has a phase shift of about 180 degrees with said  
22 unshifted phase section, said half tone section has a transmittance  
23 between about 0.1 and 98 %;

- 1                   b) transmitting radiation through portions of the phase shift mask to expose  
2                   a pattern of photoresist overlying a semiconductor work piece; and  
3                   c) utilizing the patterned photoresist to fabricate a semiconductor device.

4   55. The method of claim 54 wherein:

- 5                   said first phase shift section comprised of a first phase shift region of a  
6 mask substrate;  
7                   a trench in said first phase shift region; and  
8                   said half tone section comprised of (i) a half tone region of said mask  
9 substrate and (ii) a half tone layer over said half tone region;  
10                  said second phase shift section has about a 0 degree phase shift.

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12   56. The method of claim 54 wherein :

- 13                  said first phase shift section comprised of (i) a first phase shift region of  
14 a mask substrate and (ii) a first trench in said first phase shift region;  
15                  said half tone section comprised of a half tone region of said mask  
16 substrate and a half tone layer over said half tone region; said half tone layer has a  
17 transmittance between about 3 and 30%; and  
18                  said second phase shift section has about a 0 degree phase shift.

19   57. The method of claim 54 wherein said half tone layer has a transmittance between about  
20    3 and 30%.

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